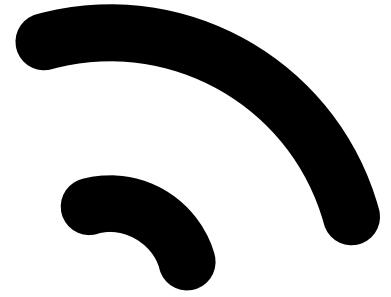


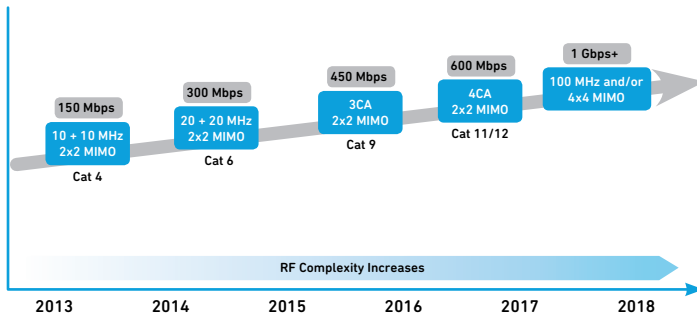
# Carrier Aggregation

## What's New in Mobile CA



Commercial LTE networks started with category 3 and 4 devices supporting 100 to 150 Mbps with continuous 20 MHz spectrum. Category 11/12 brought 600 Mbps during 2016, with data rates of 1 Gbps expected to start in 2017.

LTE category downlink bandwidths above 20 MHz require at least 2 component carriers (CC), above 40 MHz requires at least 3 CC and above 60 MHz requires at least 4 CC.

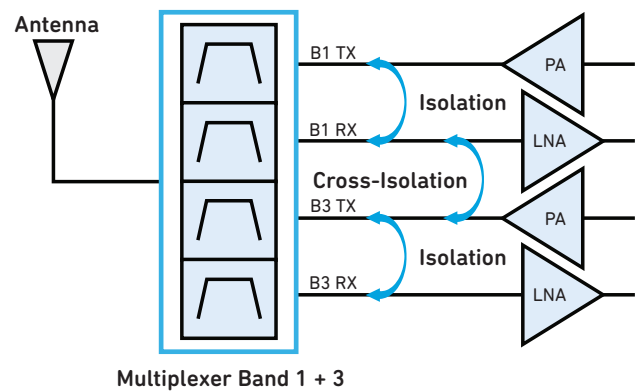


Aggregated DL BW	DL Data Rate	Modem Class
10 MHz	75 Mbps	-
15 MHz	100 Mbps	LTE Category 3
20 MHz	150 Mbps	LTE Category 4
25 MHz	185 Mbps	-
30 MHz	225 Mbps	-
40 MHz	300 Mbps	LTE Category 6/7
50 MHz	375 Mbps	-
60 MHz	450 Mbps	LTE Category 9/10
80 MHz	600 Mbps	LTE Category 11/12

- Above assumes 64 QAM in the downlink
- The scaling in data rate between 64 QAM and 256 QAM is a factor of 1.33 (8 bit symbol versus 6 bit symbol)

Enabling CA requires simultaneous communication on multiple CCs. In some cases the RF front end must support multiple transmit and/or receive paths between the antenna(s) and transceiver. Isolation of these paths requires multiplexed RF filters or physically separated antennas. Achieving cross-isolation calls for matched filters that attenuate the out-of-band signals to avoid loading the other aggregated bands. In addition, each filter must have low insertion loss to minimize transmit power consumption and optimize phone receiver sensitivity.

### Band 1 + 3 Multiplexer Requires High Isolation Between Tx and Rx Ports



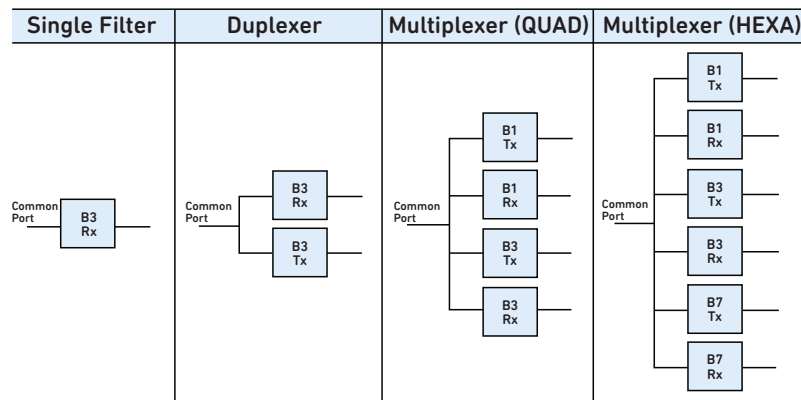
### Carrier Aggregation Band Combinations That Require Multiplexers

Band Combination	Multiplexer	Separate Antenna	Primary Region of Use
B1 + B3	x		China, Korea, Europe
B25 + B66	x		North America
B3 + B7	x	x	Europe, Middle East & Africa
B1 + B3 + B7	x	x	Korea
B3 + B7 + B20	x	x	Europe, Middle East & Africa
B39 + B41	x		China
B1 + B3 + B8	x		Japan

# Downlink CA

3DL and 4DL CA solutions can be implemented in multiple ways depending on the band combinations and associated challenges. Multiple antennas may solve some challenges, but more complex filters are often required. Cascaded duplexers, triplexers, quadplexers, and even higher order multiplexers like hexaplexers and septaplexers are being employed to solve system level problems. It is important to manage the insertion losses of these filters to meet system link budget requirements.

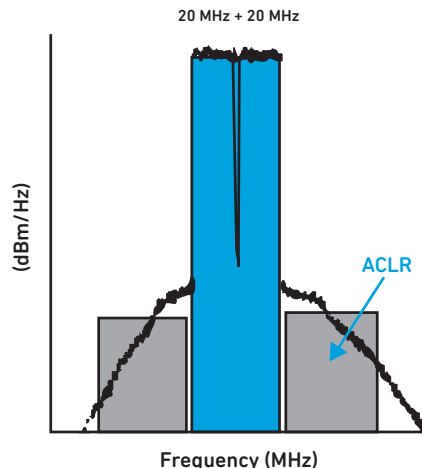
## Single Filters, Duplexers and Multiplexers



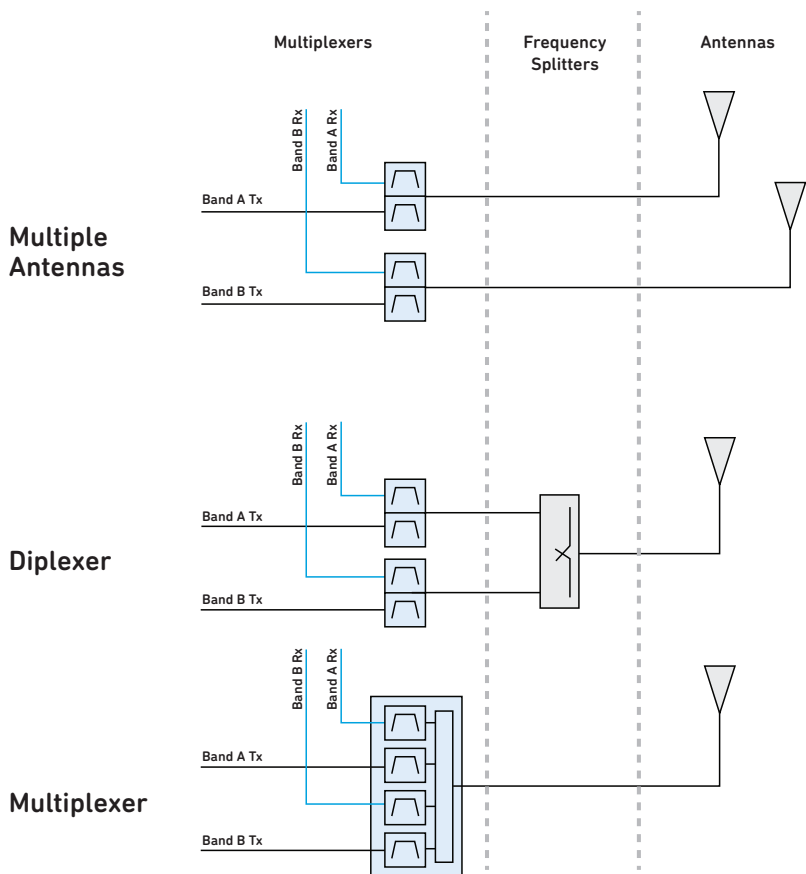
# Uplink CA

LTE uplink carrier aggregation (ULCA) is the latest global sensation in cellular. ULCA improves the user experience by enabling new trends in social video and gaming. ULCA combines two or more LTE CCs, transmitted from a single user device, increasing the speed a user can upload content.

## Channel Bandwidth and ACLR



## 3 Front End Architectural Approaches Supporting CA



Intra-band ULCA uses wider bandwidth signals than other LTE cases. These signals require power amplifiers designed with wider bandwidth and higher linearity (ACLR, SEM and EVM). Envelope tracking converters similarly require wider bandwidth capabilities.

Some inter-band ULCA combinations require high linearity switches to ensure low IMD products from two high Tx power signals. An example is B1/B3 ULCA where the IMD3 products can desense B1 Rx and GPS.